AD-A072 389 HONEYWELL INC ST PETERSBURG FLA F/G 17/7

LIMS. LASER INERTIAL MEASUREMENT SYSTEM.(U)

JUL 78 DAAK40-76-C-0665

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1 OF 1

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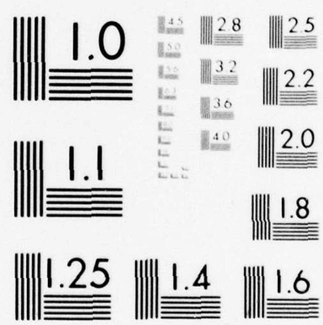
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(2)

B.S.

AD A072389

(6) LIMS. Laser Inertial Measurement System.

(9) FINAL TECHNICAL REPORT,

(11) July 1978

(12) 17p.

PREPARED FOR

THE

U.S. ARMY MISSILE RESEARCH

AND

DEVELOPMENT COMMAND

In Compliance With

Contract DAAK40-76C0665 New

CDRL ITEM 004

(15) DAAK40-76-C-0665

Honeywell Inc.
13350 US Highway 19 North
St. Petersburg, Florida 33733

170190

DISCLAIMER NOTICE

A - Aims and Objectives

Under Contract DAAK40-76-C-0665 perform the design, development, build and acceptance of Laser Inertial Measurement System (LIMS) for the Simplified Inertial Guidance Demonstration (SIG-D) Program as described in Technical Requirements No. 6035, 16 January 1976.

B - Positive and Negative Results of effort

B1 - Positive results

Acceptance and delivery of the items described in Section I of TR No. 6035 was accomplished. Special Test Equipment (STE) and Laser Inertial Measurement Unit (LIMU) acceptance to a MIRADCOM approved Acceptance Test Procedures occurred as listed below:

Test Period	Items Accepted
8/29/77 thru 9/6/77	Operational Support Equipment (OSE) Launch Control Unit (LCU)
11/11/77 thru 11/20/77	System Support Equipment
	LIMU #3 (Vibration Requirement waived)
1/4/78 thru 2/10/78	LIMU #1
2/4/78 thru 2/10/78	LIMU #4
2/23/78 thru 3/2/78	LIMU #2
3/17/78 thru 3/24/78	LIMU #5

A summary acceptance test report ~~has been~~ was provided to MIRADCOM for each LIMU delivered.

The anomalies and/or failures during these acceptance test were primarily due to remaining hardware development problems and procedure development problems, not unusual for new items.

After these developmental problems were solved, the LIMU's capability of meeting the requirements established for it was adequately demonstrated as evidenced by the fact that the last four acceptance tests were accomplished in a 2 month interval and were routine in nature.

B2 - Negative Results

As a result of problems in the design and development cycle of the Guidance Control Computer (GCC), deliveries of software and hardware items were behind schedule.

The first and second attempt to acceptance test the LIMU and STE in August and October 1977 respectively, were aborted due to GCC halts, SSE malfunctions and failure to meet the vibration performance requirements. The vibration requirements were waived for acceptance of LIMU #3 in November 1979.

The stability of the porror prism with respect to the accelerometer triad was near the 100 micro radians budgeted in all acceptance tests. This is discussed in detail in the problems section of this report.

C - Problems Encountered and Their Solutions

Summarized below are the significant problems encountered during LIMS acceptance testing and the resultant solutions or recommendations. The Design Change Notice (DCN's) are referenced for completeness but are not included in this report.

Problem #1 - GCC Noise Susceptable

Description - During acceptance testing (aborted) of LIMU #1 (GCC #5) in January/February 1978, RAM memory alterations occurred during +28 VDC transients.

Cause : The conductance of the +5 VDC Hi and Lo circuitry in the GCC CPU #1 and CPU #2 trays was not sufficient to prevent the buildup of "noise" signals on this circuitry under all conditions. These noise signals on the 5 VDC would occasionally result in an unscheduled state change of logic in the CPU trays.

Solution: Two modifications were incorporated. The first, incorporated via DCN's 203, 204, 206 and 207 (September 1977) increased the conductance capability of the +5 VDC Hi and Lo circuitry. The second modification, incorporated via DCN's 266 and 267 (February 1978), increased the capacitive coupling between the +5 VDC Hi and Lo.

Problem #2 - SSE Overtemp Protection Malfunctions

Description - During the acceptance testing of LIMU #1 and SSE #1 in August/September 1977, the following anomolous behaviors of the overtemp protection circuitry were observed.

a) With the OT override switch in the off position, on occasion, erroneous changes to the GCC and AT overtemp condition would occur. These changes were not dependent on whether the GCC and AT were connected to the SSE.

If the change was from a non-overtemp to an overtemp state, shutdown of the system +28 vdc resulted (after correction of anomaly described below in "b" and with the OT Monitor selection switch properly positioned) and

b) with the OT override switch in the "off" (protect) position, shutdown would occur only if both the GCC and AT were in the overtemp state.

Cause : a) When the SSE ETI spring mechanism is rewound, current surges on the 28 vdc and return occur as a DC rewind solenoid is energized. This "noise" on the return line would occasionally cause the GCC and AT overtemp latches (U6 in the Power Control Logic, P/N 34027146) to set resulting in the system shutdown.
b) An error in the design of the decision logic for a shutdown condition (part of the Power Control Logic, P/N 34027146).

Solution: a) Decoupling circuitry was added at the ETI. In addition the ETI return was moved from the positive side of the system current sense resistor to the low side. These changes were accomplished via DCN's 1216, 1226 and 1227.
b) Logic corrected so a shutdown will occur if either AT or GCC are in the overtemp state. Change accomplished by DCN 1196

Problem #3 - <u>+350 VDC Monitor Voltage Polarity Incorrect</u>

Description - During the acceptance testing (aborted) of LIMU #1, SSE #1, in Aug/Sept 1977, the polarity of the +350 VDC at the SSE Power Control Panel was negative.

Cause : Design error. The +350 HI was wired to the monitor return and the +350 LO to the monitor HI.

Solution: Via DCN 1196, the wiring was corrected in the Power Control Panel.

Problem #4 - <u>Prelaunch Sequence Test Result Out of Spec.</u>

Description - During the acceptance testing (aborted) of LIMU #1 in Aug/Sept 1977, the computed change in azimuth after erection from +3 degrees pitch to +54 degrees pitch was 0.2 degrees when the actual change was near zero.

Cause : The sign of the Z axis porra alignment with respect to the accelerometer triad (Calibration Parameter POZ) was incorrect. This condition was a result of an incorrect input to the Calibration Program describing the relationship of the Porro axes with respect to the accelerometer axes (ANGC in the ISA* data set).

Solution: The ISA* data set was corrected.

Problem #5 - Failure to Load GCC Memory Using High Speed Control Unit (HSCU) #4

Description - During the acceptance testing of LIMU #3 and SSE #1 in November 1977, on two occasions the GCC EAROM could not be loaded when HSCU #4 was being used.

Cause : In the first instance, a diode case was shorted to a transistor case in the HSCU. In the second instance, the SSE HSCU interface board, S/N 02, malfunctioned.

Solution: The shorted condition was removed. The HSCU interface board was replaced with S/N 01. Additional details are provided in LIMU #3 Acceptance Test report.

Problem #6 - Failure to Meet Vibration performance requirements.

Description - During acceptance testing of LIMU #1 in Aug/Sept 1977 (aborted), LIMU #3 in Oct 1977 (aborted) and LIMU #3 in Nov 1977, the velocity and position performance requirements for vibration testing were not consistently met.

Cause : Extensive evaluation testing in Oct/Nov 1977 revealed miniscule rotations of the Ring Laser Gyro (RLG) assemblies with respect to the Gyro Triad chassis were taking place when the Gyro Triad was subjected to vibration. These rotations were sensed by the respective individual gyros, and when processed, caused erroneous changes to the attitude matrix which in turn propagated into velocity and position errors. The cause of the rotations was determined to be due to the gyro mounting bolts, ¼ inch, 300 series, stainless steel bolts, being in the yield region, as a result of the specified 75 inch pound torque. This in turn resulted in the forces excerted on the RLG assembly during vibration to exceed the yield strength of the mounting bolts.

Solution: Two corrective actions were implemented. The first, and most significant, was to change the RLG mounting bolt from the 300 series stainless to a type having a higher yield strength (new build will use 400 series stainless steel but due to a long lead time on 400 series stainless steel bolts, it was necessary to use cold rolled black oxide coated steel on existing devices). The second change was to insure a minimum mechanical couple by adding a copper shim with a one inch inner diameter between the RLG assembly and the gyro triad. For new build, this couple can be accomplished by the gyro triad casting and the copper shim eliminated. The changes were implemented via DCN 250.

Problem #7 - Undetected Gyro Triad Air Leaks

Description - During Temperature/Altitude testing portion of LIMU #3 acceptance testing in Oct 1977 (aborted), arc over of the high voltages occurred when the LIMU was subjected to a simulated 50K feet altitude. To insure integrity of the unsealed RLG's, it was necessary to return them to Honeywell Minn. for BOI and retest. The High Voltage Power Conditioner. which was damaged beyond repair, was scrapped and a new one installed.

Cause : A gross leak existed around the gyro triad connector J2. Since the Gyro Triad seal integrity is required to prevent corona when operating the LIMU at near vacuum conditions, this leak allowed a vacuum to be pulled on the Gyro Triad and the resultant arc-over. The leak was undetected because there was no way to verify seal integrity after closure.

Solution: A Schrader valve was added to the Gyro Triad via DCN 231. This valve provides the capability to verify the seal integrity. In addition, a leak test requirement was added to the LIMS Acceptance Test Procedure. It should also be noted that the addition of the Schrader valve lead to the discovery of porosity in the GT casting. As a result, all GT castings were vacuum impregnated under authority of DCN 252.

Problem #8 - Apparent Porro Prism Instability

Description - The stability of the alignment of the porro prism with respect to the accelerometer triad, exceeded the 100 miro-radian ATP requirement during acceptance testing of LIMU #4 and LIMU #5. Supporting data is provided in paragraph G of this report.

Cause : Four sources of the instability were identified and corrective actions implemented.

One source of instability was determined to be due to the relaxation of stresses induced during the assembly process. A second source of instability was determined to be porro prism movement as a function of Gyro Triad chassis temperature with a scale factor of approximately 1 sec/°F. This movement is a result of a bi-metallic effect of the stainless steel prism mounting base in conjunction with the aluminum Gyro Triad chassis. When the LIMU is calibrated in a room ambient of approximately 75°F, the Gyro Triad chassis tempterature stabilizes at approximately 115°F. From a cold start, the stabilization time is approximately 3 hours, but at 2 hours the temperature is within 5°F of the stabilized temperature. Optical prism readings taken prior to reaching the stabilized state were therefore divergent from those taken after stabilizing.

A third source of instability was determined to be the porro prism alignment sensitivity to the torque applied to the LIMU mounting bolts, and the sequence in which these bolts were torqued.

A fourth source of instability was determined to be the amount of bearing surface between the porro prism mounting bracket and gyro triad strucutre. As the bearing surface was increased, the stability improved.

Solutions: To overcome instabilities due to relaxation of stresses a procedure was inplemented to force the relaxation by performing a minimum of three thermal cycles from -45°F to +145°F on the ISA assembly. These thermal cycles were accomplished on new build, after a gyro removal and installation and after the accelerometer triad was removed and installed.

To overcome instabilities which resulted if optical data was taken prior to stabilization of the gyro triad chassis temperature, a procedure was implemented to make all porro prism optical measurements at the end of a calibration when the LIMU will have had power applied for at least 2 hours. In addition, a study was conducted to determine the impact of this sensitivity on the mission CEP. The effect increased the one sigma CEP from 131.92 to 137.9 feet. A revision to the SIG-D Navigation Accuracy Analysis, HI document ED21694 has been provided.

The sensitivity to LIMU mounting bolt torque and the sequence these torques are applied was corrected by requiring that the LIMU always be torqued to 125 inch pounds in a specific sequence (Reference figure 7-14(d)) in the ATP. In evaluation test of this requirement, it was demonstrated that the porro prism alignment repeatability is less than 4 arc seconds when this procedure is followed.

To increase the bearing surface between the porro prism mounting bracket and the gyro triad structure to a realistic maximum, three NAS620CIDL washers, ground to .028 thick ±.0001, were placed between the prism bracket and GT structure. This change was implemented via DCN 187. In the evaluation test of this change, the unit was thermal cycled three times for a total of nine cycles between -40°F and +145°F with the result being a shift in alignment from baseline of 21 arc-seconds in elevation and 1.3 arc-seconds in azimuth after the first thermal cycles and minimal shifts after the next two thermal cycles with the final deviation from baseline being 15.3 arc-seconds in elevation and 1.9 arc-seconds in azimuth.

Recommendation - Except for the change to take optical readings at the end of a calibration sequence, all of the discussed corrective actions were implemented prior to acceptance testing of the LIMU's. To gain insight into which element was the major contributer to the apparent porro prism instability, the datas obtained during the LIMU acceptance testing were reduced to determine the porro prism stability with respect to the gyro triad and movements between the accelerometer triad and gyro triad in the x, y, z coordinate frame. (Graphs of these results are provided in paragraph G of this report.) For LIMU's 1, 2 and 3, the results are inconclusive. For LIMU's 4 and 5, the predominant source of instability is movement of the accelerometer triad (AT). This movement of the AT appears to be bounded to within 200 micro-radians, and for the demonstration tests will not be a major error contributer. Undoubtedly, the source of this movement could be isolated and corrective action implemented for future systems.

D - References Used

The following have been referenced in this report:

SIG-D LIMS Acceptance Test Procedure
Design Change Notices

E - Calculations Required for Complete Definition

None.

F - Tables and Charts of Results and Significant Data

None.

G - Other Applicable Data and Calculations Generated in the Program

Figures 1 through 5 were derived from Acceptance Test Calibrations and are relative to the discussion of problem #8 in paragraph B of this report. The acronyms used on these graphs are as follows

M XX YYY

- YYY — Calibration Number
- XX — LIMU Serial Number
- M — MIRADCOM

GAU,V,W - Gyro Align W/R to Accel Frame in components coordinate frame

GOU,V,W - Gyro Orthogonality about U, V, W Gyro Axes

AOU,V,W - Accelerometer Orthogonality about U,V,W Accelerometer Axes

POYz, POZa - Porro Align W/R to Accel Orthogonal Frame rotated into the X,Y,Z Frame

POY_G, POZ_G - Porro Align W/R to Gyro Orthogonal Frame rotated into the X,Y,Z Frame

AAX,AAY,AAZ - Accel Orthogonal Frame W/R to Gyro Orthogonal Frame in the X,Y,Z Coordinate Frame

H - Photographs, Drawing, etc.

None

I - Conclusions and Recommendations

The simplified Inertial Guidance Demonstration Laser Inertial Measurement System, a complex set of flight software, calibration software, support software, flight hardware, laboratory test hardware and launch support hardware, provides to the Army a powerful capability to evaluate a ring laser gyro based system for Army applications. The SIG-D LIMS meets the requirements established in TR6035. It is expected that the MIRADCOM conducted sled and flight tests of the LIMS will be highly successful.

Unexpected problems were encountered in the design and development of the Guidance Control Computer, and resulted in program delays. The problems encountered in the design and development of the Gyro Triad and Accelerometer Triad were typical for new designs. The system Support Equipment, the majority of which is a laboratory version of the GCC, had similar development problems to those encountered with the GCC.

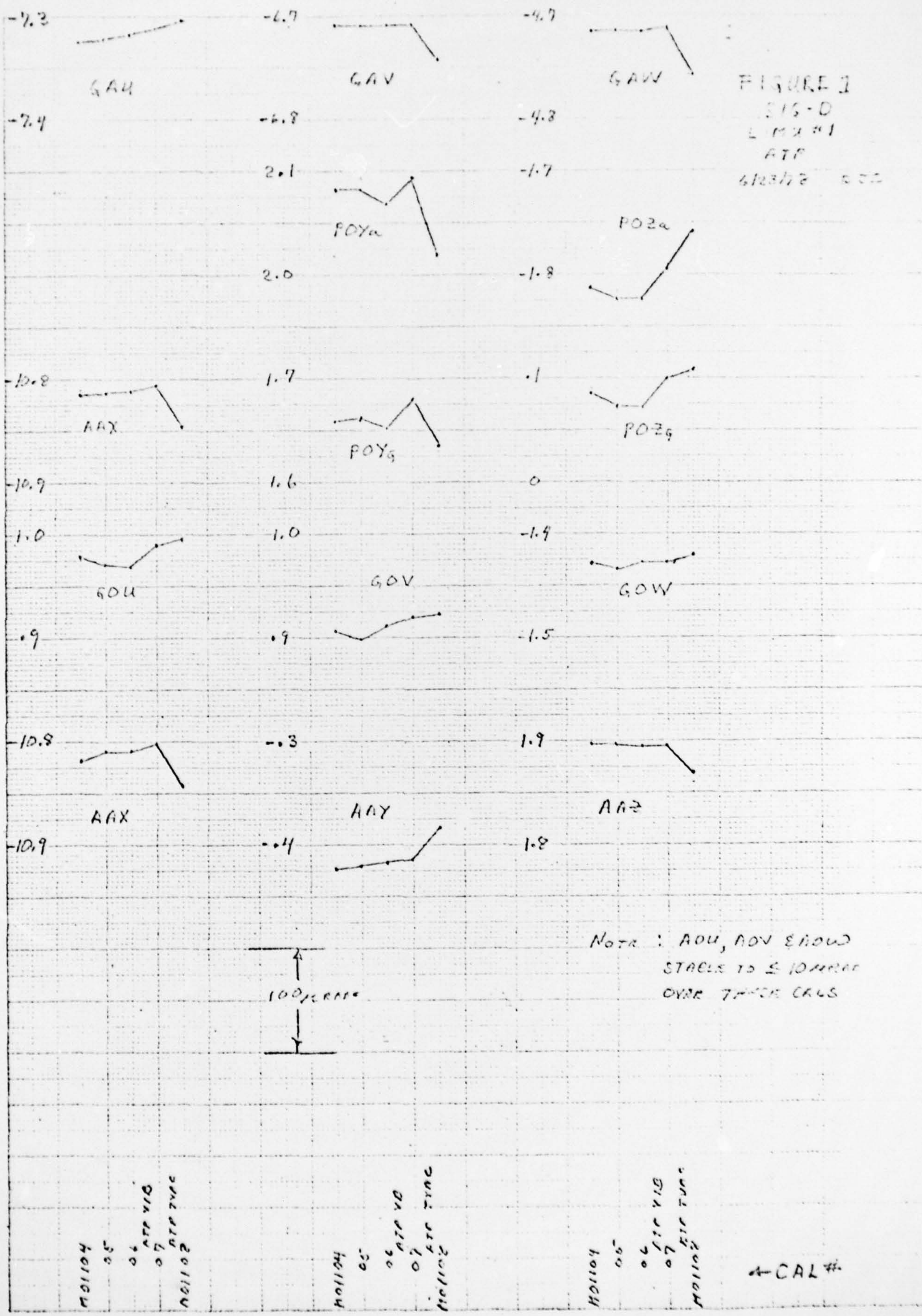

FIGURE 1
SIG-D
LMX #1
ATP

Note: AOU, AOV shown stable to ≤ 10 μrad over these cals

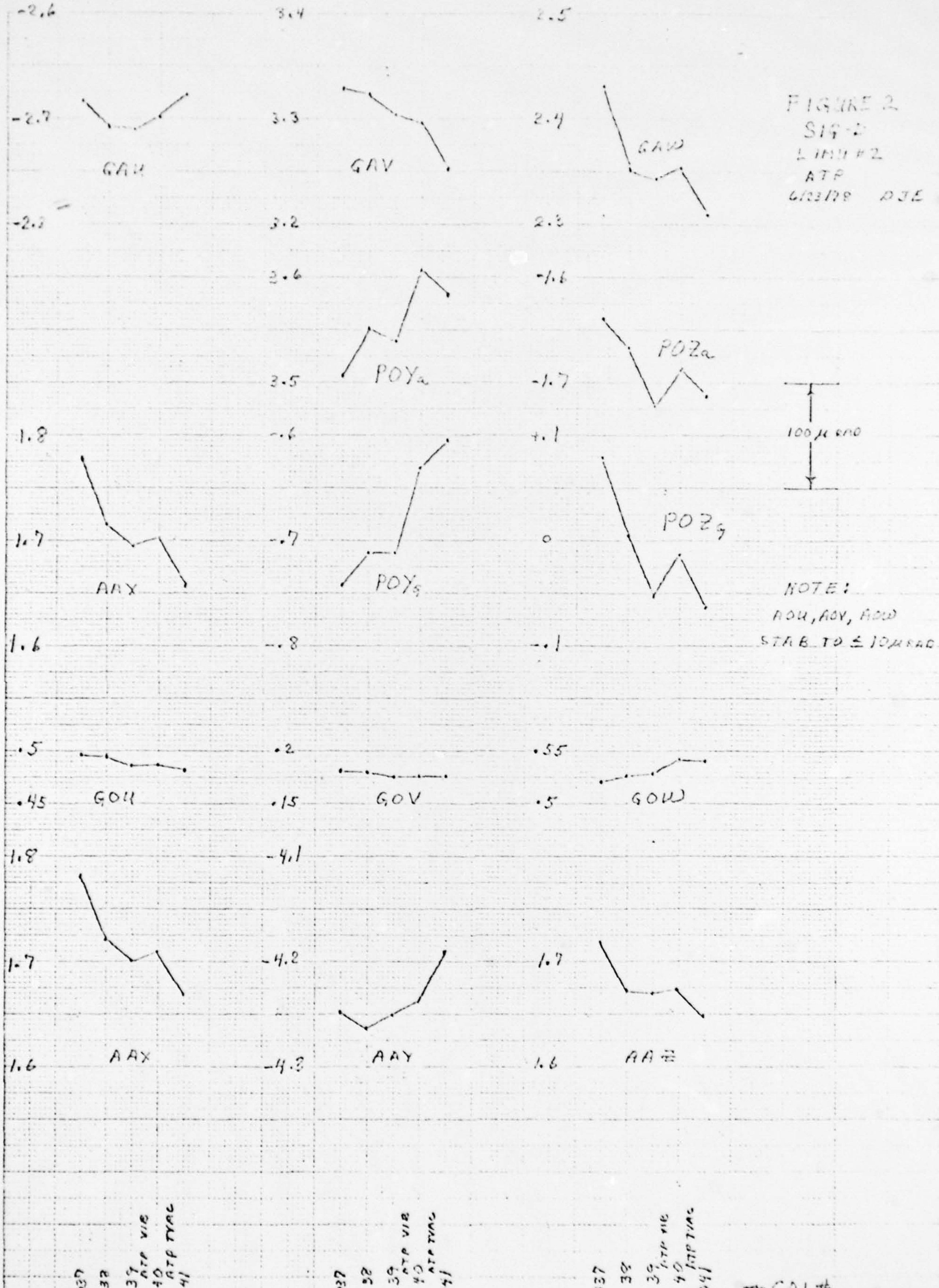

FIGURE 2
SIG-2
LIMU #2
ATP
6/23/78 DJE
-2.6
-2.7
GAU
3.4
3.3
GAV
3.2
2.5
2.4
GAW
2.3
3.6
POYa
3.5
-1.6
POZa
-1.7
100 μ RAD
1.8
1.7
AAX
1.6
-.6
-.7
POYg
-.8
+.1
0
POZg
-.1
NOTE:
AOU, AOV, AOW
STAB TO ± 10 μ RAD
.5
.45
GOU
.2
.15
GOV
.55
.5
GOW
1.8
1.7
AAX
1.6
-4.1
-4.2
AAY
-4.3
1.7
AAZ
1.6
M02037
38
39 ATP VIB
40 ATP TVAC
M02041
CAL #

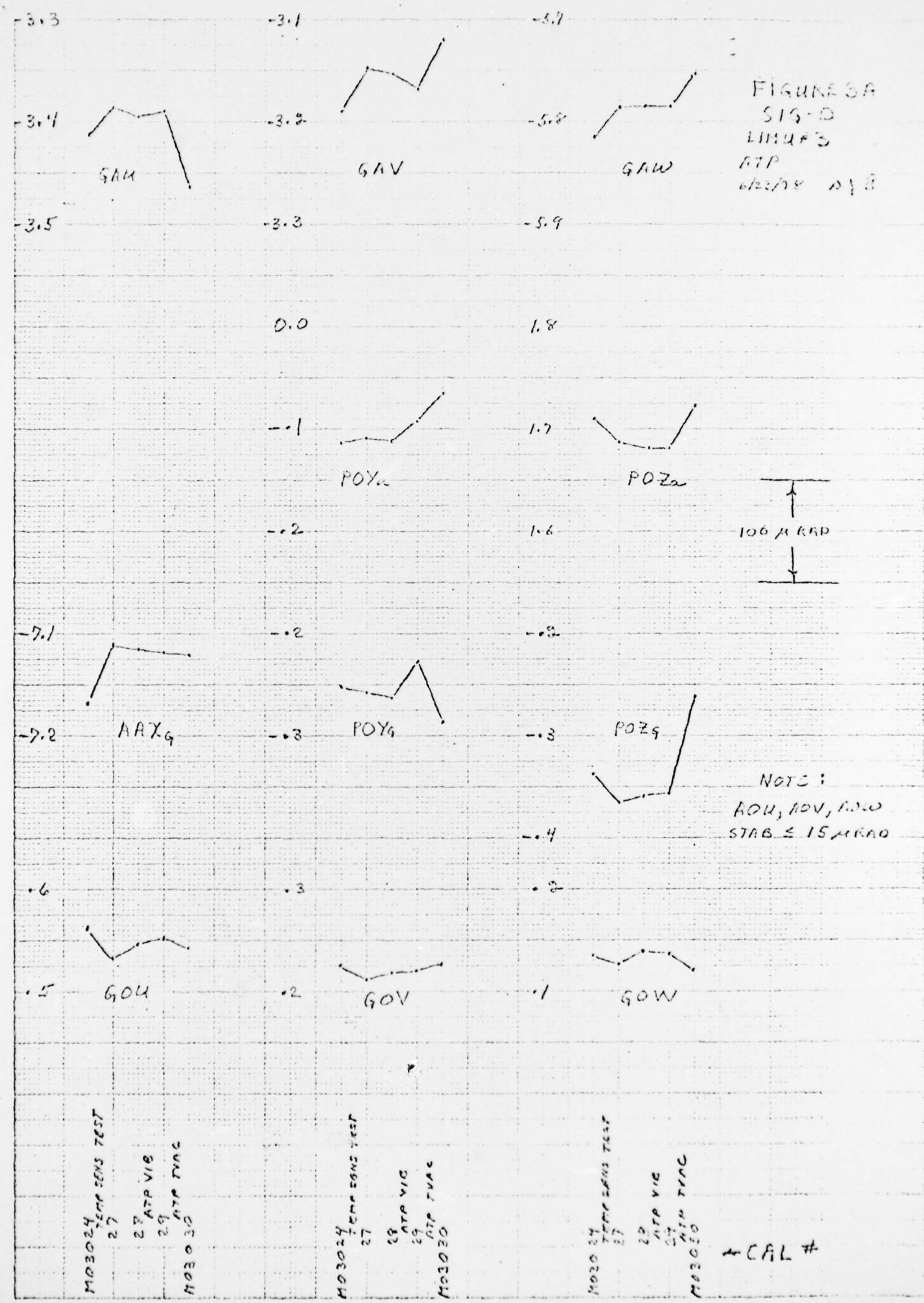
FIGURE 3A
SIG-D
GAU
GAV
GAW
POYa
POZa
100 μ RAD
AAXg
POYg
POZg
NOTE:
AOU, AOV, AOW
STAB ≤ 15 μRAD
GOU
GOV
GOW
MO3024 TEMP SENS TEST
27 ATP VIB
29 ATP TVAC
MO3030
← CAL #

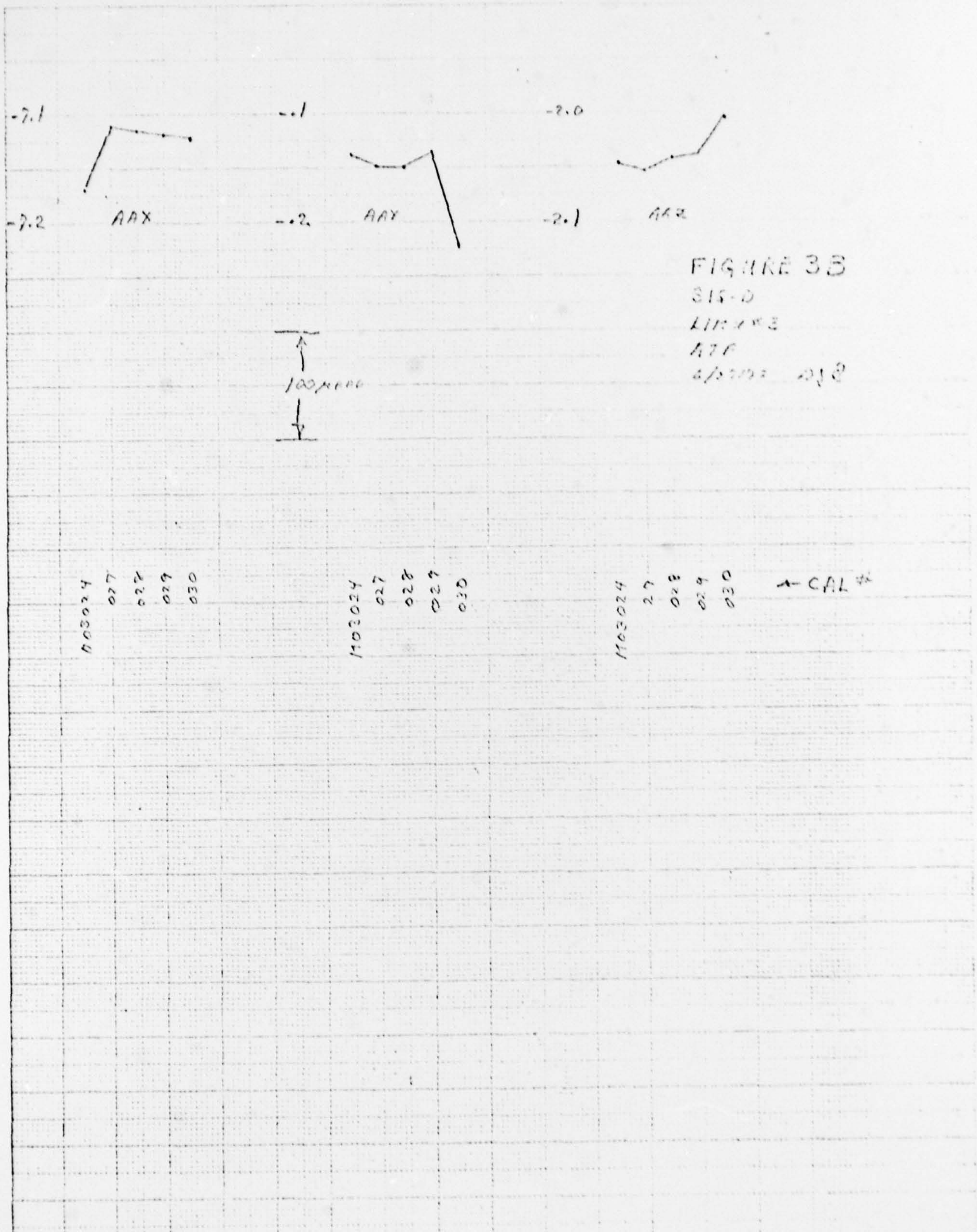

FIGURE 3B
S15-D
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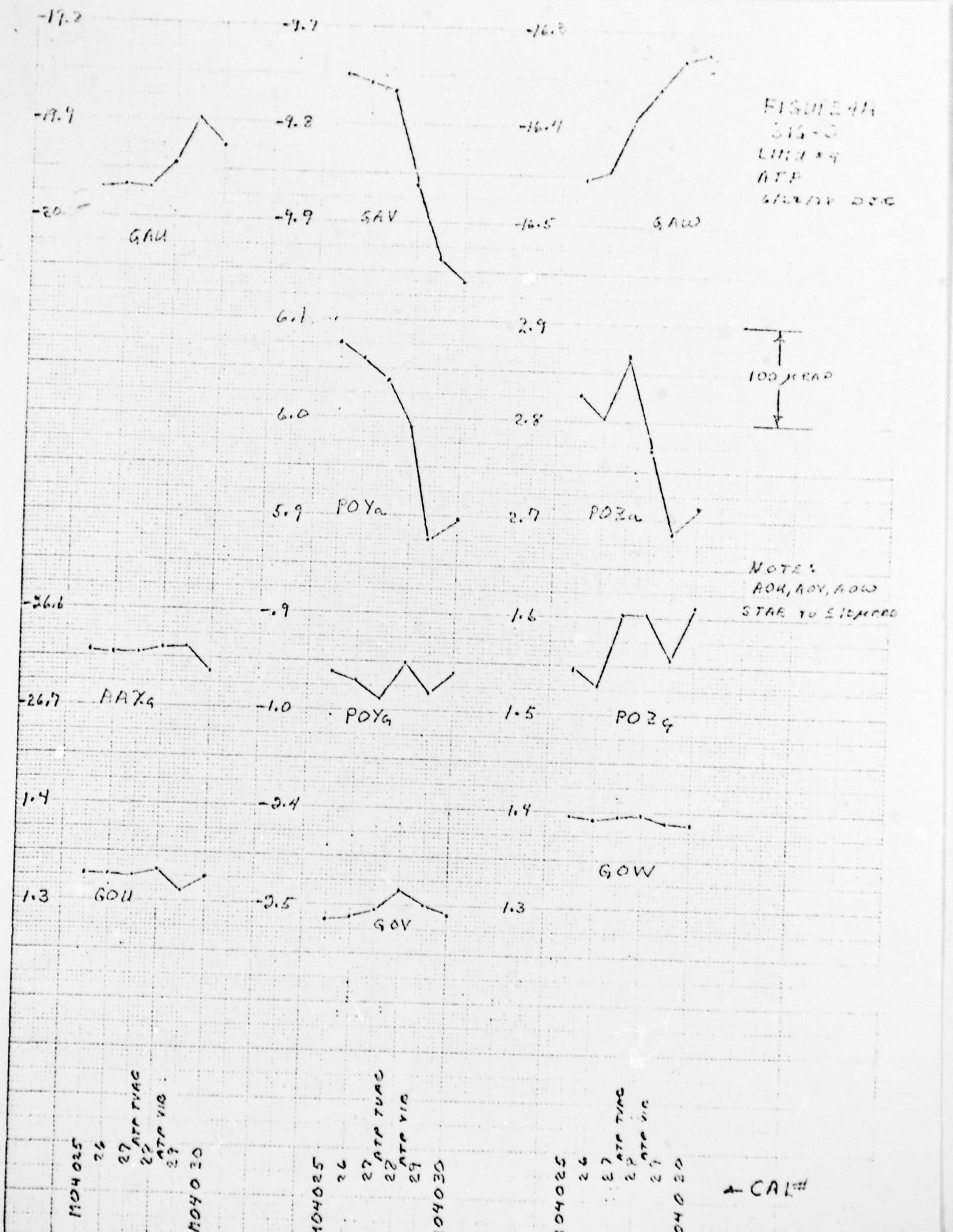
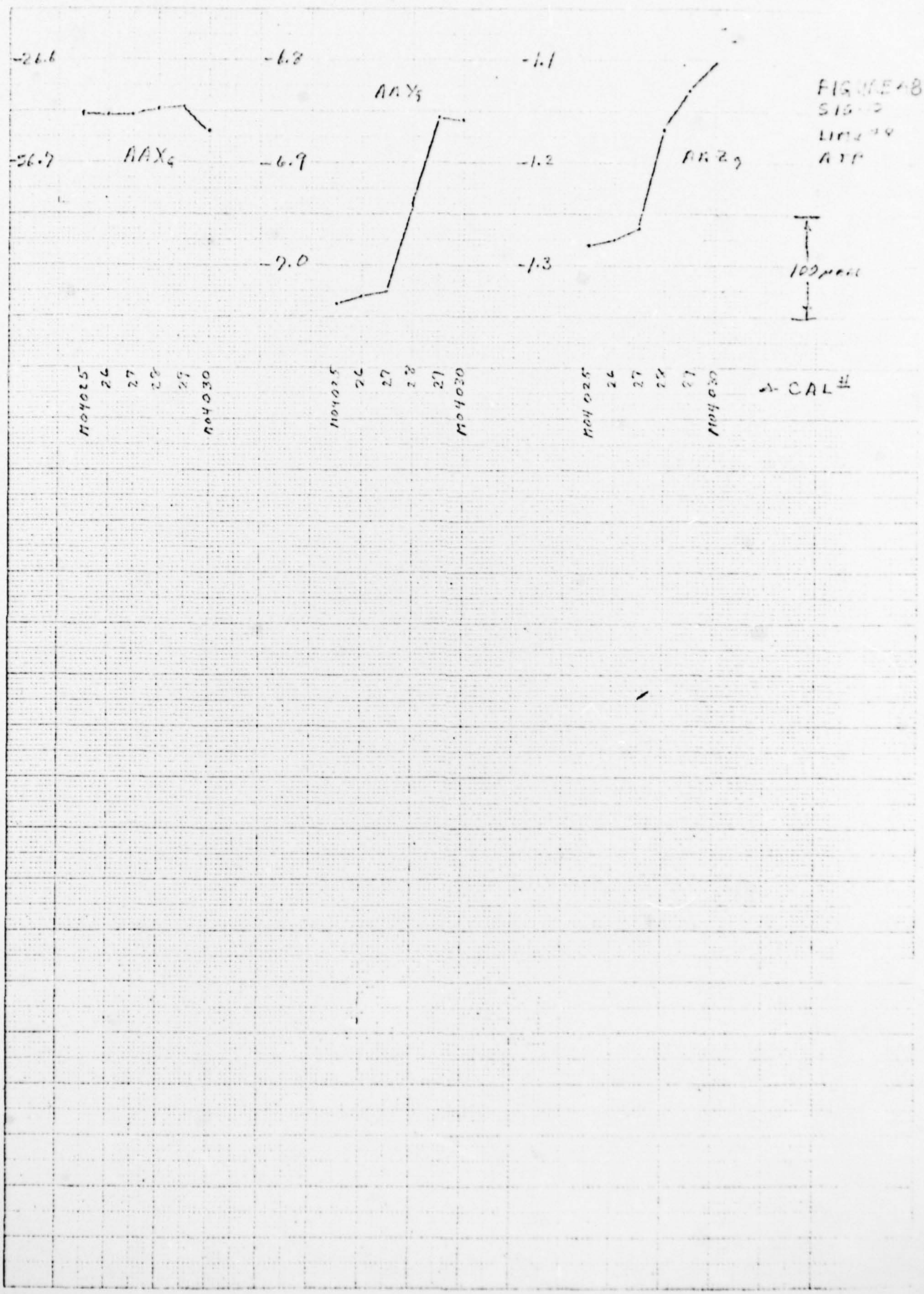


FIGURE 4R
LINE #4
ATP
-19.8
-19.9
-20
GAU
-9.7
-9.8
-9.9
GAV
-16.3
-16.4
-16.5
GAW
6.1
6.0
5.9
POYa
2.9
2.8
2.7
POZa
100 μRAD
NOTE:
AOU, AOY, AOW
STAR TO ≤ 10 μRAD
-26.6
-26.7
AAXg
-.9
-1.0
POYg
1.6
1.5
POZg
1.4
1.3
GOU
-2.4
-2.5
GOV
1.4
1.3
GOW
MO4025
26
27
ATP TVAC
28
ATP VIB
29
MO4030
← CAL#


-26.6
-26.7
AAX6
-6.8
-6.9
-7.0
AAY5
-1.1
-1.2
-1.3
AAZ9
FIGURE 8
100 μcell
M04025
26
27
28
29
M04030
← CAL #

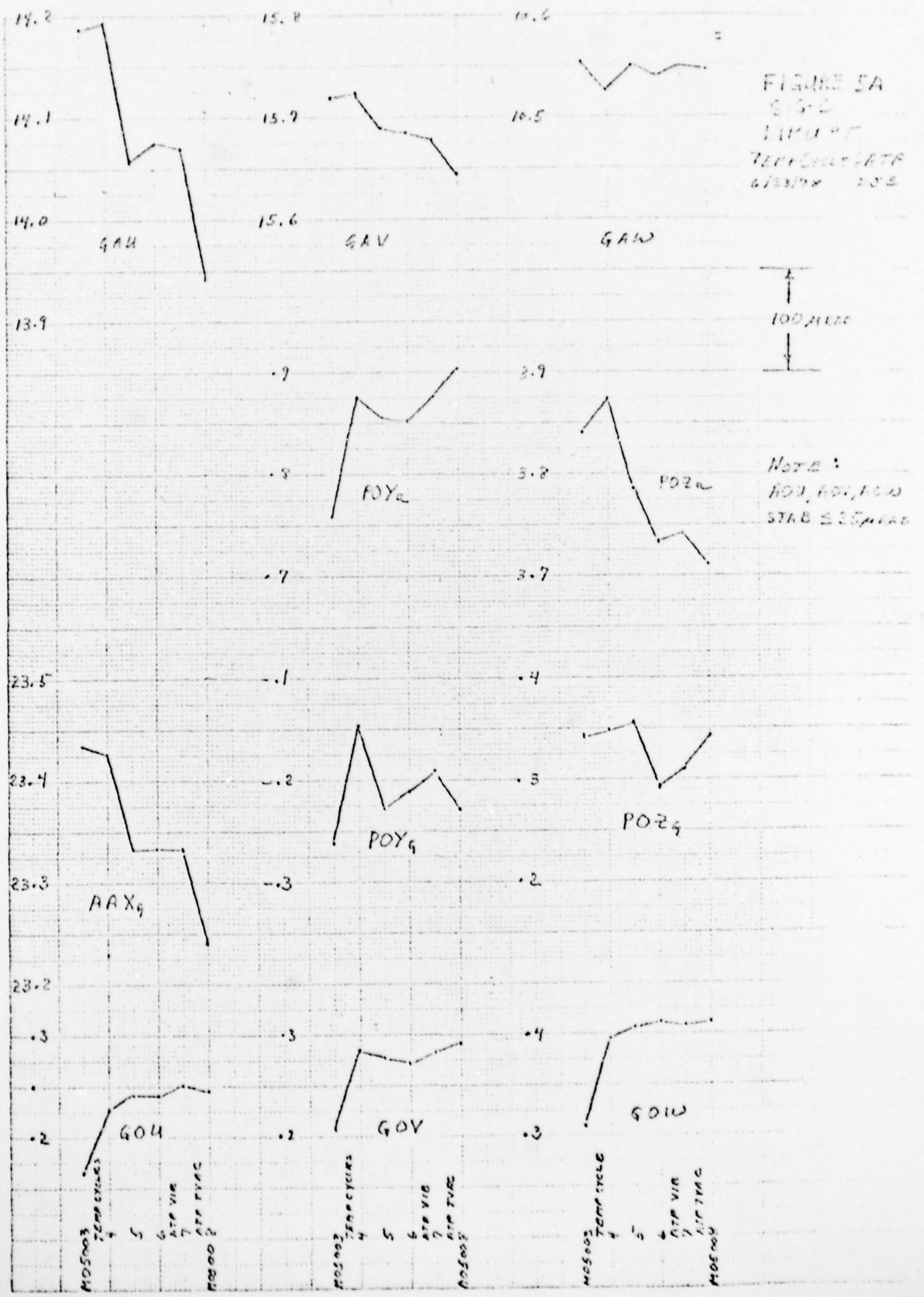


FIGURE 5A
GAU
GAV
GAW
100 μrad
POYa
POZa
Note:
AOU, AOV, AOW
STAB ≤ 25 μrad
AAXg
POYg
POZg
GOU
GOV
GOW
MOS003
TEMP CYCLES
ATP VIB
ATP TVAC

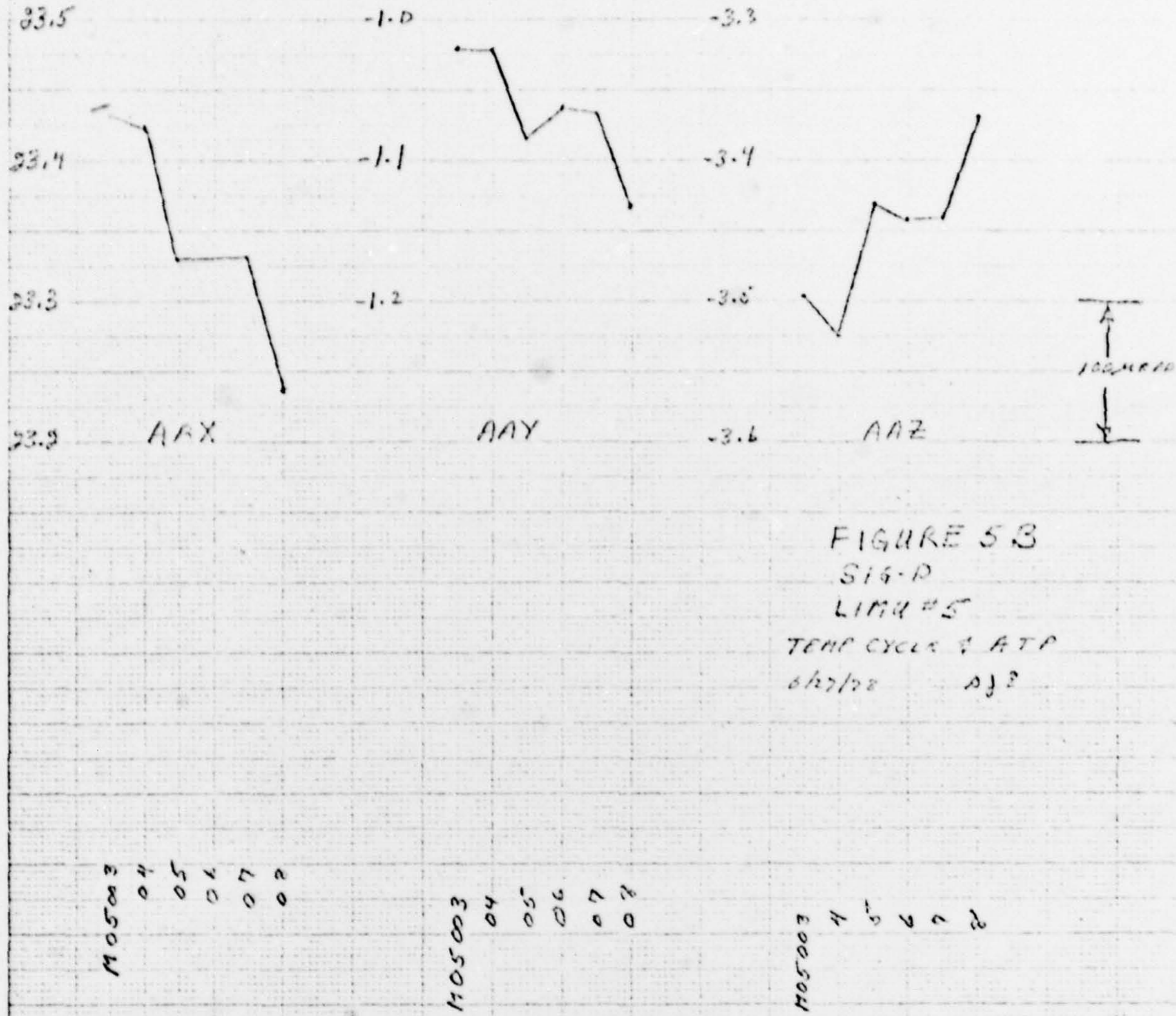


FIGURE 5B
SIG-P
LIMU #5
TEMP CYCLE & ATP
6/27/78 AJB